Urban Sprawl and Farmland Prices

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A theoretical model of farmland valuation is developed to explicitly account for three effects of urban sprawl: conversion of farmland to urban uses, effect on agricultural returns, and speculative effect as represented by farmland conversion risk. This model is estimated using county-level data in the continental United States. Evidence is found for all three effects of urban sprawl on farmland values. Counties more accessible to major urban centers have higher net agricultural returns. Subsidiary evidence supports that the latter effect may be attributed to survival of (or conversion to) high-valued agriculture around urban centers.

Key words: hedonic determinants, land prices, spatial econometrics, urban sprawl.

Urban sprawl and land use has become a major policy issue since the 1980s. The expansion of urban areas has reduced farmland around many major metropolitan areas (Greene and Stager 2001). This conversion of farmland to urban uses has led to higher farmland values, particularly in areas of rapid urban growth (Shi, Phipps, and Colyer 1997). This article determines whether the higher farmland prices in urban areas can be partly explained by higher returns to farmland near urban areas.

The urban growth model of Capozza and Helsley (1989) has been used to estimate the effect of urbanization on farmland values at the parcel (Cavailhes and Wavresky 2003) and county level (Plantinga and Miller 2001; Hardie, Narayan, and Gardner 2001; Plantinga, Lubowski, and Stavins 2002). Hardie, Narayan, and Gardner (2001) estimated the model using county-level data from six mid-Atlantic states. Their results indicate that the response of farmland values to changes in development is more elastic and greater in rural counties, while response to changes in farm returns is inelastic and relatively uniform for rural and urban counties. Plantinga, Lubowski, and Stavins (2002) use the stochastic version of the Capozza and Helsley (1990) model to decompose farmland values into rents from agricultural production and future land development. Their results suggest that the option value associated with irreversible and uncertain land development is capitalized into current farmland values.

The idea behind the urban growth model of Capozza and Helsley (1989) as well as other models of urban sprawl (Arnott and Lewis 1979; Wheaton 1982; Brueckner 1990) is that current farmland values represent the current value of future agricultural and potential development rents. This formulation assumes that the return to agricultural production initially exceeds the return to urbanization until the value of urban use increases enough to trigger conversion. As a result, land far enough from a city sells for its discounted rents from agriculture, while farmland close to the urban-rural boundary sells for a premium that is equal to the present value of anticipated increases in rent after the land is converted to urban use (development component).

However, proximity of farmland to urban centers may not only affect the development component of farmland values but may also increase agricultural rents. Urban farms may have higher returns due to reallocation of production from commodity-oriented agriculture to area-specific higher-valued alternatives or alternatively only land in high-valued crops may simply persist in agriculture. Table 1 presents the share of high-valued crops for groups of counties ranked by their 1997

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Table 1. Share of High-Valued Crops, Ranked by Accessibility Index

Number of Counties	1997 Accessibility Range	1997 Average Share of High-Valued Crops	1992 Average Share of High-Valued Crops	Accessibility Change
84	7,492.8–1,005.7	0.202	0.185	0.101
122	996.2–500.5	0.124	0.115	0.150
384	493.6–200.6	0.092	0.085	0.146
572	199.5–100.0	0.050	0.043	0.124
815	99.9–45.0	0.035	0.030	0.104
940	44.9–0.47	0.016	0.015	0.070

Notes: Quintile grouping of the counties does not alter the qualitative results.
High-value crops include vegetables, orchards, nursery, and greenhouse crops, fruits, and nuts.
Source: Authors' estimation using data from the Agricultural Census of 1997 and 1992.

accessibility or population-interaction index.[1] From this table it is apparent that counties that are more accessible to population centers have a larger share of high-valued crops such as fruits, vegetables, nursery, and greenhouse crops. This is consistent with the von Thunen formulation where higher-valued crops with relatively high transportation costs are grown in proximity to urban areas.

The novelty of this article is the examination of the effect of urban sprawl on agricultural returns, and, in turn, the isolation of this effect in determining farmland values. Hence, this article differs from previous studies that examine the effect of urban sprawl on farmland values in the United States by considering not only the effect of urbanization on future development rents but also on future agricultural returns.

In the following section we consider a farmland valuation model where the time of farmland conversion to urban uses is assumed to be a random event. Following the insights of von Thunen we develop a theoretical formulation showing that higher farmland values close to urban centers may be related to shifts in production to higher-valued crops or reduction of transportation costs. We then rely on Brueckner (1990) to model the effect of urbanization on the development component of farmland. Unlike the formulations of previous studies, our formulation includes three relationships: one for farmland pricing, one for returns to agriculture, and one for development rents. This specification isolates the relative contribution of urban pressure to agricultural returns and the contribution of urban pressures through the conversion of farmland to urban uses. Our empirical model, which is estimated with county data for the contiguous United States provides estimates for these effects, and the main result is that urban counties exhibit higher farm returns than rural counties.

Modeling Farmland Conversion

Let T be a random variable denoting the time at which farmland is converted to residential land. Once farmland is converted it remains in residential use. Location of land is indexed by the distance δ from the central business district (CBD) of the urban place. Following urban growth models (Capozza and Helsley 1989), current farmland value at time $t = 0$ and location δ is given by

(1)

$$V_A(t = 0, \delta) = E\left[\int_0^T e^{-rt} R_A(t, \delta)\, dt + \int_T^{\infty} e^{-rt} R_U(t, \delta)\, dt\right]$$

where $R_A(t, \delta)$ is the net agricultural return in time t at location δ, $R_U(t, \delta)$ is the net return to urbanization in time t at location δ (including the cost of conversion), r is the discount rate, and E denotes expectation with respect to T. The first term in the parenthesis is the stream of discounted economic rents from farming until the conversion occurs. The second term is the discounted rents from urbanized farmland, while T will be infinite if urbanization never occurs.

Given a probability distribution for T, farmland value in (1) can be solved for

$$V_A(0, \delta) = h(R_A(t, \delta), R_U(t, \delta), \lambda(t)) \quad (2)$$

[1] This index is a measure of urban pressure that increases as the population-weighted distance to urban centers decreases. A formal definition is provided in the Empirical Analysis section of the present article. For further details on its construction and available data, see Breneman (1997) or the discussion of the Population-Interaction index at the web site of the Economic Research Service of the USDA.

where $\lambda(t)$ is a parameter related to the probability distribution that governs the time of conversion T and is termed as conversion risk. It is natural to assume that the risk of conversion is negatively related to the distance δ of the parcel of farmland from the CBD and positively related to the population θ of the urban place, that is, $\lambda(\theta(t), \delta(t))$. Furthermore, because rents per unit of land decline at a decreasing rate with distance δ from the CBD (Muth 1961), the conversion risk can be specified as $\delta(t)^{-1}\theta(t)$.[2] A similar specification was used by O'Kelly and Horner (2003) to measure accessibility or the relative potential of a given location.

Following the insights of von Thunen (1966) and Ricardo (1996), farmland at different locations will have different net returns to agriculture because of differences in soil characteristics, suitability for crops with different market values, and proximity to urban centers. The latter implies that net returns to agriculture are correlated with both the net development rents and conversion risk in (2).

Effect of Urban Pressure on the Return to Farmland

To model the effect of urban pressure on the agricultural component of farmland values, we construct a profit function formulation consistent with the von Thunen effect of distance from a central place that explicitly accounts for heterogeneity in soil characteristics and climate traits of different parcels of land. Under the von Thunen formulation, higher-valued crops with relatively high transportation costs are grown in proximity to urban areas. As the distance to the central place increases agriculture becomes increasingly commodity focused.

Profit at the farm level, accounting for the spatial variation in farmland prices and differences in soil quality, where we abstract from time considerations, is given by

$$(3) \qquad \max_{\mathbf{y},\mathbf{x},A,K,D} (\mathbf{p} - \tau(\delta))'\mathbf{y} - \mathbf{w}'\mathbf{x} - rD$$
$$st \quad f(\mathbf{y}, \mathbf{x}, A, K, \mathbf{S}) = 0$$
$$(K - K_0) + (A - A_0)V_A = D - D_0$$

where $\mathbf{p}$, $\mathbf{y}$, $\mathbf{w}$, and $\mathbf{x}$ denote the vectors of output prices, outputs, input prices, and inputs, respectively; r is the interest rate on farm debt, D is the level of farm debt, $f(\cdot)$ is a multiproduct production function, A is the acres of farmland, K is the level of intermediate assets, $\mathbf{S}$ denotes soil characteristics, V_A is the value of farmland, $\boldsymbol{\tau}(\delta)$ is the transportation cost associated with each commodity, δ is the distance from the parcel of farmland to the CBD, and the subscript zeros denote initial levels. As the multiproduct production function is written in an implicit form, we assume that $f_x < 0, f_A < 0, f_K < 0, f_S < 0$ and $f_Y > 0$, where the subscripts denote partial derivatives.

From this formulation, we develop the marginal value of each unit of output given the transportation cost and the marginal value of farmland. The marginal value of each output is

$$(4) \ \partial L/\partial y_i = (p_i - \tau_i(\delta)) - \mu_1(\partial f(\cdot)/\partial y_i) = 0$$

where μ_1 is the shadow value on the production constraint (the Lagrange multiplier for the first constraint in (3)). Equation (4) yields the standard relationship that the marginal rate of transformation between two products equals the inverse of their price ratios. Note that increases in the transportation cost for each commodity implies a relative reduction in the output of that commodity. Equating the shadow value of production across all outputs yields

$$(5) \qquad \mu_1 = \frac{(p_1 - \tau_1(\delta))}{\partial f(\cdot)/\partial y_1} = \cdots = \frac{(p_n - \tau_n(\delta))}{\partial f(\cdot)/\partial y_n}.$$

Differentiating the shadow value with respect to distance then yields

$$(6) \qquad \partial\mu_1/\partial\delta = -(\partial\tau_i(\delta)/\partial\delta)/(\partial f(\cdot)/\partial y_i) \leq 0$$

as long as the transportation cost is an increasing function of distance.

Turning to the value of farmland, the first-order condition with respect to debt implies that $\mu_2 = r$ (where μ_2 is the Lagrange multiplier for the second constraint in (3)). Substituting this result into the first-order condition with respect to land values yields the standard Ricardian equation for farmland values

$$(7) \qquad V_A = -\mu_1(\partial f(\cdot)/\partial A)/r.$$

Because the partial of the multiproduct production function with respect to land is negative, (7) gives the same value as found in (2), if conversion to urban use never occurs. In particular, we are interested in specifying the net return to agricultural activities in (1) as

$$(8) \qquad R_A(\delta) = -\mu_1\partial f(\cdot)/\partial A.$$

[2] Obviously, it can also be a function of farm characteristics.

Merging the results of (5) and (8), we have

$$(9)\qquad R_A(\delta) = -\frac{(p_i - \tau_i(\delta))}{\partial f(\cdot)/\partial y_i}\frac{\partial f(\cdot)}{\partial A} = (p_i - \tau_i(\delta))\frac{dy_i}{dA}$$

where the last derivative is evaluated at the optimal point of production.

Given the results from (6) we conclude that the net return to farmland is a decreasing function of the transportation cost and distance to the market. In addition, the value of farmland is an increasing function of the relative productivity of farmland. Specifically,

$$(10)\qquad dy_i/dA = -(\partial f(\cdot)/\partial A)/(\partial f(\cdot)/\partial y_i).$$

The solution in (10) assumes that all agricultural products are produced continuously throughout the region. However, the formulation in (3) could be changed to guarantee that only nonnegative quantities of crops could be chosen transforming the problem into a Kuhn-Tucker optimization problem. The point is that not all crops would meet the marginal value condition in (5). Hence, low-valued crops may not be grown close to urban places (this relation could be offset by low transportation costs). This an important finding because it implies that higher values of farmland close to urban places are not entirely explained by agglomeration but instead may also be related to changes in crop portfolios resulting either from increased access to urban markets or conversion of (survival of) cropland dedicated to low-valued (high-valued) crops. A similar argument can be used to show that cost-inefficient farms may be absent from the outskirts of urban areas. While the intuition of the von Thunen formulation appears sound, our formulation explicitly recognizes two caveats. High-valued crops are assumed to have the highest transportation costs. Undoubtedly this assumption would be justified by the value of freshness in delivering produce. However, improvements in transportation technology and infrastructure may have flattened the von Thunen plane. In addition, differences in soil quality, climate, or economies of scale may be sufficient to offset transportation cost advantages.

Development Component of Farmland Values and Aggregate Model

We impose additional structure on the farmland valuation model by specifying the determinants of the net return to urbanization. Following, the open-city model of Brueckner (1990), we assume that the preferences of urban residents can be represented by the utility function $U(C_l, C_{nl}, \theta)$, where C_l is consumption of land, C_{nl} is consumption of a numeraire nonland good, and θ is urban population. Assuming that individual land consumption is fixed at one unit per person the budget constraint becomes $R_u + C_{nl} + k\delta = M$, where M denotes income, R_U is urban land rent, and $k\delta$ is the commuting cost from a residence to the CBD of the city, with $\delta \leq \delta^b$ denoting this distance (δ^b is the distance from the urban boundary to the CBD). Solving for this utility maximization problem, the returns to urbanization should satisfy

$$(11)\qquad R_U = R_U(\delta, \theta)$$

where urban land rent is a decreasing function of distance to the CBD. The effect of population on urban rent can be either negative or positive depending on whether the disamenity effect (Brueckner 1990) is greater or lower than the positive effect induced by increased demand for land.

Equations (2), (9), and (11) specify a recursive system of equations that form our empirical model of farmland valuation across space. This farmland valuation model is at the parcel level of analysis, where farmland is located around a monocentric city and farmers ship their products to the CBD of the city. Because our empirical analysis is based on two years of county data with each county containing both residential and agricultural land, we consider a county-based model where multiple cities may be observed and allow rents and distance to change over time. Therefore, we consider the following farmland valuation model at time t and distance δ:

$$(12)\qquad \bar{V}_A(t,\delta) = F_1(\bar{R}_A(t,\delta), \bar{R}_U(t,\delta), \bar{\lambda}(\theta(t), \delta(t)))$$

$$(13)\qquad \bar{R}_A(t,\delta) = F_2(\delta(t), \bar{S}(t))$$

$$(14)\qquad \bar{R}_U(t,\delta) = F_3(\delta(t), \theta(t), \bar{M}(t))$$

Following Plantinga, Lubowski, and Stavins (2002) we define $\bar{R}_A(t,\delta)$ as the average (per acre) net return to agriculture in the vicinity of δ (county specific). Similarly, $\bar{V}_A(t,\delta)$ and $\bar{R}_U(t,\delta)$ are defined as the average farmland value (per acre) and net return to development, respectively. In (13), $\bar{S}(t)$ denotes the average soil characteristics in the county, while in (14) (net returns to development equation), we include median residential income ($\bar{M}(t)$) as an exogenous variable to relax the homogeneous income assumption. The conversion risk $\lambda(\theta, \delta)$ has been defined as a function of population and distance to a CBD. We replace this measure and $\delta(t)$ with accessibility index $\bar{\lambda}(\cdot)$ that accounts for the average distance of any given location in a county to multiple cities and is weighted by the population of each city.

With the advent of geographic information systems (GIS), hedonic studies of this type are increasingly being done with parcel-level data rather than county-level data (e.g., Ready and Abdalla 2005). Studies using GIS have the advantage of measuring distances precisely. GIS data might be preferred when measuring the distance for a specific amenity or disamenity that only has an effect for a short distance, such as the distance from a school. Clearly, parcel-level data has the potential to achieve more precise estimates. But, as a practical matter, GIS studies typically consider only one or a few urban areas due to the cost of data collection. Urban areas can differ in many ways such as zoning ordinances so the urban area studied might not be representative of the entire United States. Using county-level data makes it practical to estimate an average effect of urban pressure.

Furthermore, the distance from the CBD is still an imperfect measure of urban pressure even if measured precisely with GIS. The parcel-level data also frequently have outliers. Using aggregate data can reduce the effect of error in measuring distance and greatly reduce the influence of outliers. If the relationship between value and distance is nonlinear, aggregation introduces a different form of measurement error. Also, due to the fewer degrees of freedom, estimation with county-level data is not as precise (less efficient) than estimation with parcel-level data. But, the precision gained from estimation with disaggregate data is often quite small (Wu and Adams 2002; Richter and Brorsen 2006). Clearly, there are tradeoffs between using parcel-level and county-level data. We argue that studies using both types of data are complements, because they each allow addressing an aspect that the other does not.

Empirical Analysis

The farmland valuation model, equations (12)–(14), serves as the basis for our econometric model, which is estimated using data on all counties in the contiguous United States for the years 1992 and 1997. The estimated model is then used to estimate the relative magnitude of urban and agricultural components on net returns to agriculture and on farmland values. The data were collected from the Census of Agriculture (1997), the Census of Population and Housing (2005), the Economic Research Service (ERS; 2005) of the United States Department of Agriculture (USDA), the National Climatic Data Center (2005), and the Bureau of Economic Analysis (2005).

Farmland value as expressed in (12) can be decomposed into three parts: the effect of net agricultural returns, the effect of nonfarm opportunities as represented by the net returns to development, and the speculative component of urban pressure as measured by the conversion risk (i.e., accessibility measure). Assuming a log-linear specification for (12) the farmland value equation is given by

$$\begin{aligned} &(15)\\ &\ln \bar{V}_{A,it}\\ &= a_0 + a_1 \bar{R}_{A,it} + a_2 \ln \bar{H}_{it} + a_3 \bar{R}_{A,it} \ln AC_{it}\\ &\quad + a_4 \ln \bar{H}_{it} \ln AC_{it} + a_5 YD_t + \mathbf{a}_6'\mathbf{FR}_i + u_{V,it} \end{aligned}$$

where for each county i in year t, $\bar{V}_{A,it}$ is the average market value of farmland and buildings (in dollars per acre), as reported in the Census of Agriculture. This represents the average value of undeveloped parcels located among the cities and the county boundary.

The average net returns from agriculture (in dollars per acre) are given by $\bar{R}_{A,it}$. Using data from the Census of Agriculture, $\bar{R}_{A,i}$ at time t was computed as $(TR_i - TC_i + GP_i)/A_i$, where TR_i is the dollar value of all agricultural products sold, TC_i is the total farm production expenses, GP_i are the total government payments received by farmers, and A_i is the approximate land in farms (acres).

Because housing is the most important use of urban land (Brueckner and Fansler 1983), we used the county median value (dollars) of single-family homes on less than 10 acres without a business or medical office on the property, $\bar{H}_{it}$, as a proxy for the returns to urbanization at the urban fringe.[3] By using this variable we make an implicit assumption

[3] While a per-acre median house value would be more plausible for the model, we lack data on the mean lot size and the value that this lot represents in the median house value. Such data are reported only for the four main census regions of the United

that single-family homes are constructed at the urban boundary. This proxy serves also in capturing implicitly the cost of converting farmland to residential use, as its value reflects both the price of the land and the house. Data on county median house values were taken from the decennial Census of Population and Housing (Summary Tape File 3). We used the House Price Index provided by the Office of Federal Housing Enterprise Oversight (2005) and linear extrapolation and interpolation to project the 1990 and 2000 values to 1992 and 1997. This index is reported quarterly at the state level and tracks changes in the price of single-family homes.

As a proxy for the conversion risk $\bar{\lambda}(\cdot)$ we used the accessibility index AC_{it}, which is a population-weighted sum of inverse distances within 50 miles of any given location in the county. Formally, the accessibility of a single location s (5-kilometer grid cell) within a county i is defined as $AC_{sj} = \theta_j/\delta_{sj}$, where θ_j the population of cell j, δ_{sj} is the distance from cell s to cell j, and we have surpassed the subscript t. To assess the effect of proximity to multiple urban centers, the accessibility index is aggregated across a number J of possible locations. Thus, the accessibility index of location s in county i is given by $AC_s = \sum_{j=1, j\neq s}^{J} \theta_j \delta_{sj}^{-1}$, where j represents one of the J grid cells within a 50-mile radius of cell s. The threshold of 50-mile radius allows for a higher level of regional variation than cut-off points with greater radius (O'Kelly and Horner 2003). The county accessibility index AC_{it} is then an average value for all locations s in the county.

To control for differences between the two years of data due to changes in interest rates or other variables that have a common effect in all observations, we included a year dummy, YD_t, that allows for a different intercept for each year of the sample (1 for 1997 and 0 for 1992). A vector $\mathbf{FR}_i$ of nine farm resource regions (dummies) that depict the geographic distribution of U.S. farm production[4] was added to control for unobserved differences among regions due to different types of farms, commodities produced, soil, and climatic traits. Also, we assume that the random error term $u_{V,it}$ follows a spatial autoregressive process.

Furthermore, to correct for inflation we converted all economic variables to 2000 dollars using the personal consumption expenditures component of the implicit GDP deflator. Given the implicit nonlinearity of (2), all variables in (15) are transformed in logarithmic form except for the dummies and net returns to agriculture ($\bar{R}_A$). The latter variable was specified as linear, given the existence of negative net returns to agriculture for many counties for both years in the sample. In addition, this specification allows separating the agricultural and development components of farmland values.

The second equation of our empirical model relates the average net returns to agriculture to the full set of productive and locational attributes of the farmland in the county

$$\begin{aligned} \bar{R}_{A,it} &= b_0 + b_1 AC_{it} + \mathbf{b}_2'\bar{\mathbf{S}}_i + b_3 PI_{it} \\ &\quad + \mathbf{b}_4'\mathbf{PDSI}_{it} + b_5 YD_t + \mathbf{b}_6'\mathbf{FR}_i + u_{R,it} \end{aligned} \tag{16}$$

where all variables are specified as linear; $\bar{R}_{A,it}$, AC_{it}, YD_t, and $\mathbf{FR}_i$ are the same variables as in (15); and $\bar{\mathbf{S}}_i$ is a vector of soil characteristics[5] that was obtained from ERS and captures effects due to soil properties and quality across counties (see table 3 in the results section). To further control for heterogeneity across counties we included the percentage of irrigated acres, PI_{it}, as reported in the Census of Agriculture, that is expected to have a positive effect on $\bar{R}_{A,it}$. In addition, climatic differences across counties are captured by three average values of the Palmer Drought Severity Index ($\mathbf{PDSI}_{it}$) that correspond to the planting, harvesting, and fallow seasons. It is a water balance index that considers water supply (precipitation), demand (evapotranspiration), and loss (runoff) for each county. It was obtained from the National Climatic Data Center and is reported by climatic divisions of each state. Finally, unobserved differences across counties that affect net returns to agriculture are captured by the farm resource dummies ($\mathbf{FR}_i$).

The explanatory variable of primary interest in (16) is the distance to the markets where producers ship their products. If there was a single

States. Furthermore, we lack data for the house value on the urban fringe at the county level. Thus, as in Hardie, Narayan, and Gardner (2001), we used median house values.

[4] The farm resource regions have been developed by the ERS and are constructed grouping counties with similar types of farms and produced commodities; and soil, climatic, and physiographic characteristics. The heartland region was dropped from the analysis.

[5] The same data set of soil characteristics was utilized for both years in the sample. A formal definition of each variable can be found at the web site of the Natural Resources and Conservation Service of the USDA (2005).

Table 2. Generalized Spatial 3SLS Estimates for the Farmland Value Equation

Variable	Coefficient Estimate	Standard Error
Intercept	1.467*	0.206
Net returns to agriculture ($\bar{R}_{A,it}$, \$/acre)	0.006*	0.000
Median single-family house value ($\ln \bar{H}_{it}$, \$)	0.404*	0.020
Accessibility index interaction ($\bar{R}_{A,it} \ln AC_{it}$)	−0.001*	0.000
Accessibility index interaction ($\ln \bar{H}_{it} \ln AC_{it}$)	0.022*	0.001
Year dummy (YD_t, 1997 = 1)	0.016	0.017
Northern Crescent region	0.025	0.026
Northern Great Plains region	−0.451*	0.036
Prairie Gateway region	−0.276*	0.028
Eastern Uplands region	0.008	0.025
Southern Seaboard region	0.017	0.025
Fruitful Rim region	−0.075*	0.029
Basin and Range region	−0.243*	0.035
Mississippi Portal region	−0.046	0.035
Spatial autocorrelation coefficient (ρ_V)	0.099	

Notes: Dependent variable is the natural logarithm of farmland value ($\ln \bar{V}_{A,it}$, \$/acre) and Heartland region was dropped as a base. The asterisk denotes significance at the 5% level or higher.

market, distance could be measured by actual transport cost or physical distance, but in a region such as the United States it is generally unknown who supplies whom (Benirschka and Binkley 1994). Thus, we use the accessibility index in each county as a measure of distance.

As shown in the previous section, returns to urbanization are conditional on income, population, and distance to the CBD. Thus, based on (14) and the above reasoning for the specification of development rents as median house values, a log-linear specification for median house values is given by

(17)

$$\ln \bar{H}_{it} = c_0 + c_1 \ln \bar{M}_{it} + c_2 \ln AC_{it} + c_3 DPD_{it} + c_4 YD_t + \mathbf{c}_5' \mathbf{RD}_i + u_{H,it}$$

where $\bar{H}_{it}$, AC_{it}, and YD_t are the same variables as in (15). The median household income (dollars) in county i at time t, $\bar{M}_{it}$, was taken from the decennial Census of 1990 and 2000, through the Regional Economic Information System. To find the corresponding values for 1992 and 1997 we followed a similar interpolation as in the case of median house values, where we used as an index the per capita personal income of each county for the period 1989–2000. The variable DPD_{it} denotes the average residential population growth rate in county i during the five years preceding 1992 and 1997 and was normalized in people per 1,000 acres in each county. Data on county residential population were taken from the U.S. Bureau of the Census (USA Counties 1998) for the period 1987–1997.

To control for unobserved differences across counties that affect property values, we included a set of nine regional dummies ($\mathbf{RD}_i$) that represent the geographical and historical development of the United States (Theil and Moss 2000). We dropped the Great Lakes region,[6] because it is comparable to the Heartland region that was dropped in (15) and (16).

The system of equations (15)–(17) is block-recursive and is estimated with 3,010 counties for each year, resulting in a total of 6,020 observations. This system can be written in a compact form as $\mathbf{Y} = \mathbf{ZB} + \mathbf{U}$, with $E[\mathbf{U}'\mathbf{U}] = \mathbf{\Omega} \otimes \mathbf{I}$. In this formulation, $\mathbf{Y}$ contains $\ln \bar{V}_{A,it}$, $\bar{R}_{A,it}$, and $\ln \bar{H}_{it}$, $\mathbf{Z}$ contains the explanatory variables in (15)–(17), $\mathbf{B}$ the stacked parameters of the three equations; and $\mathbf{U}$ the stacked disturbances. Tests for diagonal $\mathbf{\Omega}$ such as the likelihood ratio test and Breusch-Pagan test (Greene 2000, p. 621) rejected the null hypothesis that $\mathbf{\Omega}$ is diagonal at the 0.01 level of confidence, implying cross-equation correlation of the disturbances. As $\mathbf{\Omega}$ must be estimated, a system estimator such as three-stage

[6] This region consists of Illinois, Indiana, Michigan, Ohio, and Wisconsin. The rest of the regions are New England (CT, ME, MA, NH, RI, VT), Middle Atlantic (DE, MD, NJ, NY, PA), South Atlantic (FL, GA, NC, SC, VA, WV), North Central (IA, MN, NE, ND, SD), South Central (KS, OK, TX), Mountain (AZ, CO, ID, MT, NV, NM, UT, WY), Lower Mississippi (AL, AR, KY, LA, MS, MO, TN), and Pacific (CA, OR, WA).

least squares[7] (3SLS) or an iterated seemingly unrelated regressions (SUR) is more plausible (Lahiri and Schmidt 1978).

Given the cross-sectional nature of the data and the results of other spatial studies of farmland values (Benirschka and Binkley 1994; Hardie, Narayan, and Gardner 2001; Plantinga, Lubowski, and Stavins 2002), we allow for spatial autocorrelation of errors. Specifically, we assume that the disturbances are determined by the following first-order, spatially autoregressive process

$$\text{(18)} \quad \mathbf{U} = (\boldsymbol{\rho} \otimes \mathbf{W})\mathbf{U} + \mathbf{U}^* \quad \text{or}$$
$$u_k = \rho_k \mathbf{W} u_k + u_k^*, \quad k = V, R, H$$

where $\boldsymbol{\rho}$ is a 3×3 diagonal matrix containing the spatial autocorrelation parameters ρ_k, $\mathbf{U}$ is the spatially autocorrelated matrix of residuals, $\mathbf{W}$ is a $2n \times 2n$ (where $n = 3{,}010$ is the number of counties in each year) contiguity matrix, and $\mathbf{U}^*$ is the matrix of uncorrelated residuals. Because our model is a balanced panel of two years the weight matrix $\mathbf{W}$ is defined as diag$[\mathbf{W}_n]$. $\mathbf{W}$ is constructed so that the (i, j)th element of $\mathbf{W}_n$ is 1 if counties are contiguous and 0 if not. Furthermore, all diagonal elements of $\mathbf{W}_n$ are set to zero implying that counties are not contiguous to themselves.

A Cochrane–Orcutt transformation of (18) yields

(19)

$$[\mathbf{I} - (\boldsymbol{\rho} \otimes \mathbf{W})]\,\mathbf{Y} = [\mathbf{I} - (\boldsymbol{\rho} \otimes \mathbf{W})]\,\mathbf{ZB} + \mathbf{U}^*$$

where $E[\mathbf{U}^*] = 0$ and $E[\mathbf{U}^*\mathbf{U}^{*\prime}] = \boldsymbol{\Sigma} \otimes \mathbf{I}_{2n}$. Parameter estimates can be obtained by maximizing the corresponding likelihood function. However, this estimator is not computationally feasible for large numbers of observations. To estimate the system we adapt the stepwise generalized spatial 3SLS estimator (GS3SLS) developed by Kelejian and Prucha (2004). First, we apply two-stage least squares (2SLS) to (15), which accounts for possible measurement error of $\bar{H}$, while (16) and (17) are estimated by ordinary least squares, because both equations contain predetermined variables. Second, the residuals of each equation are used to estimate the spatial autoregressive parameters ρ_k, $k = V, R, H$, using generalized method of moments. While the asymptotic distribution of ρ_V is unknown, the spatial autocorrelation coefficients of (16) and (17) follow an asymptotic normal distribution (Kelejian and Prucha 2005). Third, using the $\hat{\rho}_k$ estimates, the system is transformed as in (19) and the disturbances of this transformation are used to estimate $\hat{\boldsymbol{\Sigma}}$. In the final step, this $\hat{\boldsymbol{\Sigma}}$ matrix is used to estimate the GS3SLS specification.[8]

Empirical Results

The estimated coefficients for the farmland value equation, as specified in (15), are presented in table 3 and most are statistically significant at the 0.05 level of confidence. As anticipated, farmland values increase with increases in the net return to agriculture, the median house value, and the accessibility index. Before correcting for spatial autocorrelation the adjusted R^2 of this equation is 0.80 but in the presence of spatial autocorrelation ($\rho_V = 0.099$), an R^2 has limited interpretation (Anselin 1988).

The estimated coefficient of the net farm returns, $(\hat{a}_1 + \hat{a}_3 \ln AC)\bar{V}_A$, implies that for the average county a \$1 increase in the sample net farm return will cause farmland values to increase by \$4.16/acre.[9] Calculating this effect for 1997 (in current dollars) we found a value of \$4.67/acre, which is similar to the results of Plantinga, Lubowski, and Stavins (2002) who, using data for 1997, find that a \$1 increase in net farm return causes farmland value to increase by \$5/acre.

The direct effect of development opportunities in farmland values is captured by $\bar{H}_{it}$, which denotes the median value of a single-family home in the county. Its coefficient calculated as $(\hat{a}_2 + \hat{a}_4 \ln AC)$ indicates that a 1% increase in the median house value results in a 0.51% increase in farmland values. Thus, at the sample average, a \$1,000 increase in the median house value results in an \$11.60/acre increase in farmland values. However, the use of county median house values instead of house values on the urban fringe may create a measurement error especially for large rural counties, which would bias the coefficients a_2 and a_4 toward zero. Because the estimated coefficients are statistically significant and have the anticipated sign, if there is a measurement error then the elimination of bias would strengthen our result.

Turning to the speculative effect of urban pressure as represented by the effect of

[7] Full efficiency in estimation requires an efficient estimator of Ω and not only a consistent estimator of Ω as in SUR.

[8] The procedures were written in gauss.

[9] The average county in our sample has the following characteristics: value of farmland is \$1,572/acre, accessibility index is 163, net farm return is \$75/acre, and house value is \$69,682.

Table 3. Generalized Spatial 3SLS Estimates for the Net Agricultural Returns Equation

Variable	Coefficient Estimate	Standard Error
Intercept	71.998*	18.760
Accessibility index (AC_{it}, see text)	0.105*	0.004
Soil texture (index)	0.259	1.627
Cation exchange capacity (meg/100g)	−0.088	0.322
Soil reaction (pH)	−7.140*	2.241
Organic matter (%)	0.919	1.045
T-factor erosion tolerance (index)	0.714	1.451
Calcium carbonate (%)	−0.833*	0.481
Water table depth (inches)	−5.340*	1.699
Bulk density (grams/ccm)	19.748*	10.397
Permeability (inches)	2.076*	1.000
Salinity (mmhos/cm)	−0.629	2.065
Drainage (index)	−1.082	1.399
Soil depth (inches)	0.505*	0.263
Three-inch rocks (%)	−0.403	0.478
Irrigated acres (PI,%)	4.209*	0.157
Palmer index ($PDSI$) – Planting season	−1.482	1.912
Palmer index ($PDSI$) – Harvesting season	−0.864	1.398
Palmer index ($PDSI$) – Fallow season	−0.630	2.073
Year dummy (YD_t, 1997 = 1)	21.486*	5.716
Northern Crescent region	8.991	8.200
Northern Great Plains region	−23.195*	10.775
Prairie Gateway region	−29.104*	8.928
Eastern Uplands region	−19.251*	8.205
Southern Seaboard region	−9.013	8.301
Fruitful Rim region	−16.276*	9.218
Basin and Range region	−49.517*	10.554
Mississippi Portal region	−48.773*	10.956
Spatial autoregressive coefficient (ρ_R)	0.101	

Notes: Dependent variable is net returns to agriculture ($\bar{R}_{A,it}$, \$/acre) and Heartland region was dropped as a base. The asterisk denotes significance at the 5% level or higher.

the accessibility index ($\hat{a}_3\bar{R}_A + \hat{a}_4 \ln \bar{H}$), we obtain that a 1% increase in its value results in a 0.19% increase in farmland value (table 3). Because distance to urban centers appears in the denominator of the accessibility index, this result implies that farmland values close to urban areas are higher than farmland values in rural areas, even after differences in the median house values have been taken into account. This result is also consistent with the findings of Archer and Londsdale (1997) who found that farmland values in metro-adjacent (metropolitan) counties were about one-third (three times) higher than farmland values in rural areas from 1978 through 1992. This persistence, apart from differences in median house values, may be attributed to the speculative demand for development (i.e., the differences in the conversion risk, or $\lambda(\theta, \delta)$ in (2)).

Most of the estimated coefficients of the farm resource regions are negative indicating that farmland values in these regions are lower than in Heartland region (region in the intercept).The dummy variable coefficient for 1997 is positive but it is not statistically significant.

Table 2 presents the estimated coefficients for the hedonic specification of the net return to agriculture specified in (16). The adjusted R^2 of the estimates without correcting for spatial autocorrelation is 0.31, which is analogous to the one found in hedonic studies (0.22–0.55) using county-level data for different sets of states of the United States (e.g., Miranowski and Hammes 1984; Palmquist and Danielson 1989; Roka and Palmquist 1997). The estimated spatial autocorrelation coefficient ρ_R is 0.101 and assuming an approximate standard normal distribution, the z-statistic for this coefficient is 34, which implies that the null hypothesis of no spatial autocorrelation can be rejected at any conventional level of confidence.

Table 4. Generalized Spatial 3SLS Estimates for the House Value Equation

Variable	Coefficient Estimate	Standard Error
Intercept	1.968*	0.156
Median household income ($\ln \bar{M}_{it}$, \$)	0.825*	0.016
Accessibility index ($\ln AC_{it}$)	0.101*	0.003
Residential population growth (DPD_{it})	4.082*	0.188
New England region	0.414*	0.028
Middle Atlantic region	0.119*	0.021
South Atlantic region	0.089*	0.015
Lower Mississippi region	0.028*	0.015
North Central region	−0.013	0.017
South Central region	−0.089*	0.017
Mountain region	0.365*	0.019
Pacific region	0.507*	0.023
Year dummy (YD_t, 1997 = 1)	0.022*	0.010
Spatial autoregressive coefficient (ρ_H)	0.102	

Notes: Dependent variable is the natural logarithm of median house value ($\ln \bar{H}_{it}$, \$) and Great Lakes region was dropped as a base. The asterisk denotes significance at the 5% level or higher.

Urban pressure can affect the value of farmland by affecting net returns to agriculture (i.e., through changes in the crop portfolio or cost structure of farms). The results in table 2 support the significance of this effect. The estimated parameter for the effect of accessibility on the net return to agriculture is positive and statistically significant at the 0.05 level. A 10% increase in the accessibility index causes the net return to agriculture to increase by 2.3% or \$1.71/acre.[10] Linking this result to the discussion above, a 10% increase in accessibility implies \$7.12/acre (or 0.45%) increase in the value of farmland independent of urban pressure from conversion or the speculative demand for farmland for eventual conversion.

Differences across counties in soil productivity, irrigated acres, and climate are captured by the soil characteristics, PI, and **PDSI** in (16), respectively. Most of these estimated coefficients are statistically significant at the 0.05 level of confidence and have the expected sign. Increases in bulk density, permeability, and soil depth are associated with increased net returns to agriculture, while soil reaction (pH), percentage of calcium carbonate, and water table depth have negative effects. Furthermore, a 1% increase in the share of irrigated farmland increases the net return to agriculture by \$4/acre, while the coefficients of **PDSI** are insignificant indicating some weak dependency with the regional dummies. The estimated coefficient for the year dummy of \$21/acre indicates that net returns to agriculture were significantly higher in 1997 than in 1992, even after such factors as increased urban pressure and differences in soil productivity are taken into account. Finally, the coefficients of the farm resource regions, which depict the geographical distribution of U.S. production, indicate that net returns in the Heartland region are higher than net returns in all other regions, except the Northern Crescent region, which has \$9/acre higher net farm returns, with all other factors held constant.

The estimated coefficients for the inverse demand for housing, depicted in (17), are presented in table 4. Before adjusting for spatial autocorrelation, our specification explains 81% of the variation in house prices even with cross-sectional data. After correcting for spatial autocorrelation, the estimated spatial autocorrelation coefficient ρ_H is 0.102 with a z-statistic of 51, and so the null hypothesis of no spatial autocorrelation can be rejected at any reasonable level of confidence.

Almost all the coefficients presented in table 4 are statistically significant at the 0.05 level of confidence and have the anticipated sign. The median value of a single-family house will increase by 0.82%, 0.10%, and 4.08% from a respective 1% increase in median household income, accessibility index, and residential

[10] Note that the average change in the accessibility index of the rural counties, as specified by the PIZA (Population Interaction Zones for Agriculture) ranking of ERS, between 1992 and 1997 was 9%. All other categories had higher average changes.

population growth. The results also indicate regional differences in the effect of house values on farmland values (along with the results of (15)). The estimated coefficients for the Pacific and New England regions imply that the median house values in those regions are, respectively, \$35,348 and \$28,846 higher than single-family house values in the Great Lakes region (the region in the intercept) with all other factors held constant. Thus, farmland values are higher in both regions than in Great Lakes region due to differences in the return to urbanization, all other factors held constant.

Finally, the estimated coefficient on the dummy variable for 1997 indicates that house values were significantly higher in 1997 than in 1992. This effect persists despite accounting for changes in other factors (i.e., changes in median income and population growth) and inflating both 1992 and 1997 median single-family house values to 2000 dollars.

The Effect of Urbanization on Farm Returns and Land Values

The model estimated in this article allows decomposing the effect of urban sprawl on farmland values into three components: the effect of changes in nonfarm opportunities as captured by the median house value variable in (15) and its determinants in (17), the speculative component of urban pressure as measured by conversion risk (i.e., accessibility coefficient in (15)), and the effect of urban pressure on net agricultural returns (i.e., accessibility coefficient in (16)). In this section we examine the relative magnitude of each effect on farmland values as well as of net farm returns, which are also decomposed into agricultural and urban (von Thunen) components.

To determine the relative contribution of accessibility (i.e., von Thunen effect) compared with the effect of soil quality attributes in the determination of net returns to agricultural assets we divide the expected value of (16) into two components:

(20)

$$\begin{aligned}\tilde{\bar{\bar{R}}}_{A,it} &= \hat{b}_0 + \hat{\mathbf{b}}_{\mathbf{2}}'\bar{\mathbf{S}}_i + \hat{b}_3 PI_{it} + \hat{\mathbf{b}}_{\mathbf{4}}'\mathbf{PDSI}_{it} \\ &\quad + \hat{b}_5 YD_t + \hat{\mathbf{b}}_{\mathbf{6}}'\mathbf{FR}_i \\ \widehat{\bar{\bar{R}}}_{A,it} &= \hat{b}_1 AC_{it}\end{aligned}$$

where $\tilde{\bar{\bar{R}}}_{A,it}$ is the net return to agriculture that is explained by soil quality, climatic, and produced commodities information, $\widehat{\bar{\bar{R}}}_{A,it}$ is the net return to agriculture that is explained by the von Thunen or urban pressure effect on the value of farm output, and $\hat{\bar{\bar{R}}}_{A,it} = \tilde{\bar{\bar{R}}}_{A,it} + \widehat{\bar{\bar{R}}}_{A,it}$ is the expected return to agricultural assets from both sources.[11]

The second column of table 5 presents the state-level relative share of the von Thunen effect $(\widehat{\bar{\bar{R}}}_{A,it}/\hat{\bar{\bar{R}}}_{A,it})$, where results have been ranked by the state mean accessibility index. These results indicate that the von Thunen component of net returns to agriculture is generally higher for states in the northeastern region of the United States. This result is consistent with the general precepts of our model. Higher-valued agriculture appears more likely in the northeastern region due to increased access to several large cities. For example, the estimate for New Jersey indicates that 47% of net returns to agriculture are attributable to increased market access, while similar results hold for states adjacent to the northeastern region.

Interestingly, accessibility to urban areas in California, Florida, Oregon, and Washington casts a relatively small footprint on net returns to agriculture despite the share of high-valued crops in each area. In these cases the presence of high-valued crops are attributable primarily to hedonic characteristics of the region (i.e., soil and climatic) and not the presence of urban areas. The spatial effect of urban pressure on net returns to agriculture at the county level is depicted in figure 1. Consistent with the results in table 5, the urban effect of net returns to agriculture exceeds 32% for most counties in Washington, D.C. to Boston corridor and around major urban centers, such as Atlanta, San Francisco, and Miami.

To examine the relative dollar per acre magnitude of each component of farmland values we define the response of farmland values with respect to a 1% change in net returns to agriculture $\varepsilon_1 = (\hat{a}_1 + \hat{a}_3 \ln AC)\hat{\bar{\bar{R}}}_A \hat{\bar{\bar{V}}}_A$, median house values $\varepsilon_2 = (\hat{a}_2 + \hat{a}_4 \ln AC)\hat{\bar{\bar{V}}}_A$, speculative component of urban pressure $\varepsilon_3 = (\hat{a}_3 \hat{\bar{\bar{R}}}_A + \hat{a}_4 \ln \bar{H})\hat{\bar{\bar{V}}}_A$, and urban pressure through changes in net farm returns $\varepsilon_4 = (\hat{a}_1 + \hat{a}_3 \ln AC)\hat{b}_1 \hat{\bar{\bar{V}}}_A AC$. We estimate these measures for each county and aggregate

[11] We include the intercept and all dummy terms in the effect of soil characteristics, because any other specification would yield implausibly large von Thunen components for many rural and greatly agricultural counties. For a similar justification see Plantinga, Lubowski, and Stavins (2002).

Table 5. The Contribution of Urban and Agricultural Components to the 1997 U.S. Net Farm Returns and Farmland Values, by State

			Change in Farmland Value ($/acre) from 1% Change in				
State	Value of Farmland ($/Acre)	von Thunen Share of $\bar{R}_A$ (in Percentage)	$\bar{R}_A$ (ε_1)	$\bar{H}$ (ε_2)	Speculative Urban (ε_3)	von Thunen (ε_4)	Mean *AC* Index
New Jersey	6,956	47.1	18.23	26.61	4.59	8.47	1,626
Rhode Island	6,186	42.4	15.37	23.98	5.78	6.29	965
Massachusetts	5,462	41.2	14.16	22.72	5.63	5.86	902
Maryland	3,316	37.5	9.31	16.66	4.79	3.61	874
Connecticut	6,221	43.8	12.52	22.79	6.50	5.49	858
Delaware	2,784	19.7	11.62	14.94	3.98	2.28	417
New York	1,350	20.3	5.77	10.48	3.52	1.24	379
Pennsylvania	2,501	31.9	6.08	12.28	3.99	2.04	351
Ohio	2,150	28.7	4.95	10.81	3.77	1.44	345
Virginia	2,027	22.6	3.88	9.36	3.58	0.95	327
Florida	2,372	14.0	12.58	12.58	2.61	1.72	302
Illinois	2,235	17.4	4.77	8.85	3.11	0.89	275
California	2,768	12.8	17.14	15.15	3.26	2.00	254
Indiana	2,172	20.7	5.40	10.25	3.53	1.15	235
North Carolina	2,186	19.0	6.00	10.60	3.58	1.18	216
Michigan	1,756	20.1	7.09	11.23	3.50	1.46	209
New Hampshire	2,385	19.1	8.20	13.74	4.74	1.69	193
Georgia	1,575	12.1	5.42	8.55	2.96	0.70	187
South Carolina	1,572	18.4	4.26	8.89	3.25	0.82	174
Tennessee	1,901	29.8	2.36	7.81	3.15	0.74	171
Kentucky	1,525	19.8	3.07	7.63	2.94	0.64	138
Missouri	1,125	10.2	3.89	6.66	2.46	0.41	130
Wisconsin	1,309	13.2	5.83	9.28	3.20	0.80	122
Louisiana	1,268	10.8	4.51	6.93	2.38	0.47	120
Alabama	1,513	15.9	3.09	7.13	2.74	0.52	116
Washington	1,271	8.7	4.01	6.57	2.69	0.30	105
West Virginia	1,150	19.1	2.15	6.49	2.65	0.43	101
Texas	628	15.8	1.55	3.90	1.58	0.27	100
Vermont	1,595	10.5	4.82	9.30	3.72	0.52	86
Mississippi	1,105	9.4	4.04	6.33	2.24	0.34	81
Minnesota	1,225	9.5	3.43	6.06	2.28	0.39	77
Iowa	1,786	9.3	3.33	6.53	2.56	0.32	71
Arkansas	1,216	4.9	9.71	8.06	2.06	0.40	70
Oklahoma	641	17.6	1.01	3.77	1.61	0.19	69
Arizona	469	9.7	2.95	5.55	2.28	0.29	60
Colorado	648	9.3	2.09	4.20	1.84	0.23	56
Oregon	1,009	6.3	2.81	4.73	2.00	0.23	46
Maine	1,257	6.6	5.79	7.90	2.92	0.44	46
Kansas	608	7.3	1.59	3.26	1.36	0.12	45
Utah	607	10.0	1.62	3.99	1.80	0.19	33
Nebraska	683	2.7	4.32	3.85	1.22	0.13	29
Nevada	413	2.9	2.13	3.33	1.56	0.07	23
Idaho	1,070	2.6	10.32	7.38	2.08	0.26	21
New Mexico	208	11.2	0.48	2.69	1.34	0.07	21
South Dakota	366	6.8	0.47	1.92	0.90	0.03	13
North Dakota	422	3.9	0.55	1.81	0.85	0.03	12
Montana	309	4.0	0.40	1.87	0.96	0.02	8
Wyoming	234	3.2	0.72	2.32	1.17	0.02	7

Notes: All economic variables are in real 2000, dollars per acre. Data are ranked by the state mean accessibility index. von Thunen Share of $\bar{R}_A$ represents the contribution of the accessibility index (*AC*) (in the net farm returns equation (19)) to the expected net farm returns. ε_i, $i = 1, 2, 3, 4$, represents the dollar per acre change in farmland value with respect to a unit percentage change in net farm return ($\bar{R}_A$), median house value ($\bar{H}$), speculative urban pressure (accessibility index in (18)), and von Thunen effect (accessibility index in (19)).

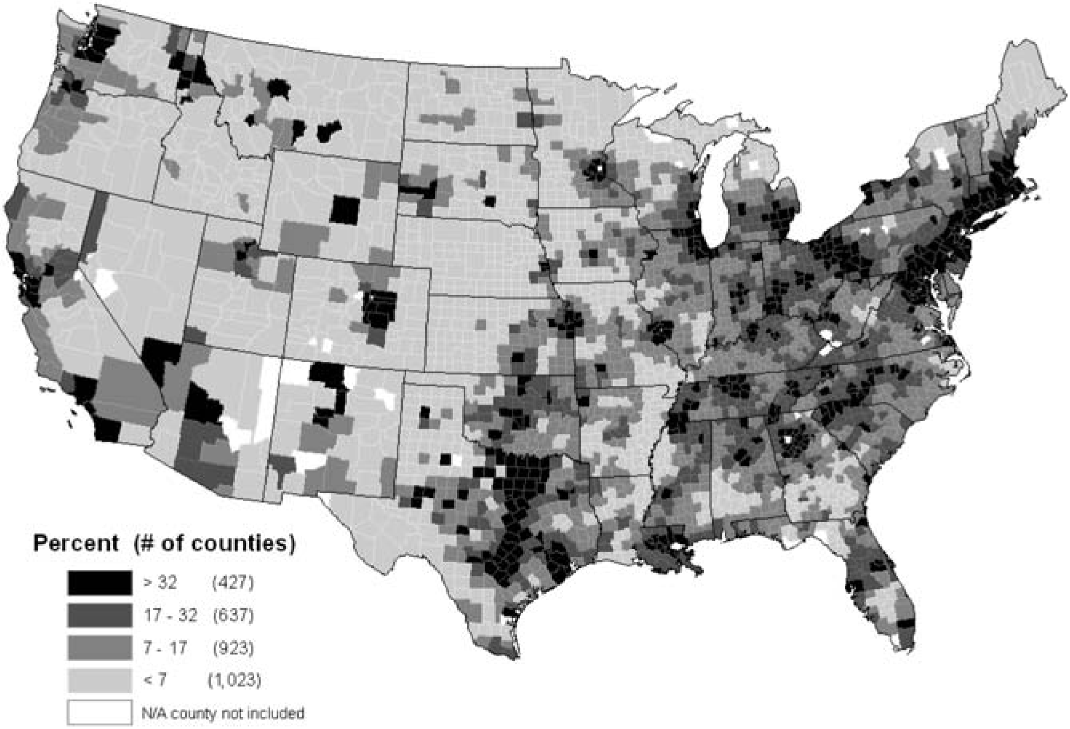

Figure 1. Estimated share of urban influence on net returns to agriculture

the county estimates to the state level using as a weight the farmland share of each county.

Results of each component along with the current farmland values (denominated in 2000, dollars/acre) and the accessibility index are presented in table 5. As in the rankings of the effect of accessibility on net returns to agriculture, farmland values in the northeastern United States are more sensitive to changes in the urban sprawl components. New Jersey is the most sensitive, where a 1% change in median house values (ε_2) (accessibility (ε_3)) increases per acre farmland values by $26.7 ($4.6) followed closely by Rhode Island and Massachusetts with an increase of $23.9 ($5.8) and $22.7 ($5.6), respectively.

In addition to their sensitivity to urban sprawl components, farmland values in these states are also sensitive to changes in net returns to agriculture (ε_1). For instance, a 1% change in net returns to agriculture causes an increase of $18.2 per acre in farmland values in New Jersey. The pure agricultural (soil quality and climate) effect is smaller if one accounts for the effect of urban sprawl on net returns to agriculture and in turn to farmland values. That is, the response of farmland values to accessibility through net returns to agriculture is also large (ε_4), mainly for the Northeastern United States. Thus, increases in farmland values from net returns to agriculture are not only connected with differences in soil productivity but also with urban pressure in the specific area.

For five states in the table, a 1% increase in net returns to agriculture will increase farmland values by more than a 1% increase in median house values. For instance, in California a 1% increase in median house values will increase farmland values by $15/acre, while a 1% increase in the net returns to agriculture will result in a $17/acre increase in farmland values. In Florida we observe that both determinants will have the same effect on farmland values. Though, in these states most of the counties that have high urbanization rates are located on their coastal side, while most of the agricultural land is located relatively far from the large urban centers.

Discussion and Implications

This article examined the effect of urban pressure on farmland values nationwide, explicitly accounting for three effects of urban sprawl: changes in nonfarm opportunities, speculative effect of urban sprawl, and changes in net agricultural returns. Traditionally, farmland values have been modeled as the discounted returns to agricultural production. More recently, several studies added the effect of urban pressure on farmland values. These studies typically focus on the impact of converting farmland to urban uses on farmland valuation. This study blends the two approaches by examining the effect of urban pressure on the net returns to agriculture as well as through potential conversion to urban use.

Our study makes two important contributions in the literature. First, using the concept of von Thunen we provide a theoretical justification and empirical evidence on the effect of urban sprawl on net farm returns. That is, we show that higher net farm returns of farmland close to urban areas are caused not only by reductions in transportation costs but also by changes in the cost structure of farms or to survival of (or conversion to) high-valued agriculture.

The second contribution of this study is the decomposition of farmland values into its components. We found that at the sample average, per acre farmland values will increase by \$4.16, \$11.60, and \$3.09 from a \$1 increase in the net return on agriculture, \$1,000 increase in median house values, and a 1% increase in the accessibility index, respectively. However, the effect of net farm returns on farmland values is overstated, because it is not only connected with differences in soil productivity but also with urban pressure in the specific area. We found that a 10% increase in accessibility yields a \$1.71/acre increase in net returns to agriculture and a \$7.12/acre increase in the value of farmland independent of direct urban pressure for conversion or the speculative demand for farmland for eventual conversion. The latter effect is mostly evident in the northeastern United States and around major urban centers, where farmland values are more sensitive to changes in the urban sprawl components (table 5). Also, it implies that a decomposition of farmland values into agricultural and urbanization components that does not account for this effect may lead to erroneous results, especially for areas that have large population growth or are located close to metropolitan areas. The portion of farmland values in urban areas that can be explained by increased agricultural returns is small, which further implies that farmland values cannot be used to compare productivity, especially for urban counties or states.

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